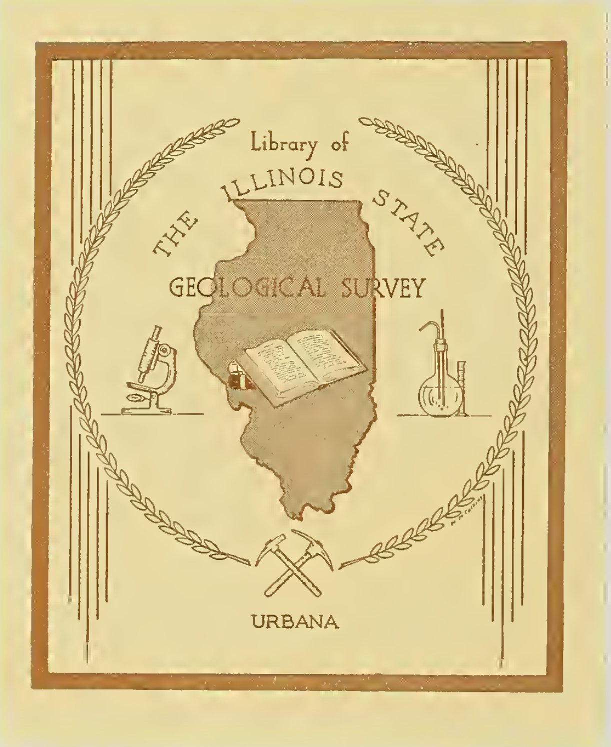

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ENVIRONMENTAL GEOLOGY NOTES

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GEOLOGICAL INFORMATION FOR MANAGING THE ENVIRONMENT

JOHN C. FRYE

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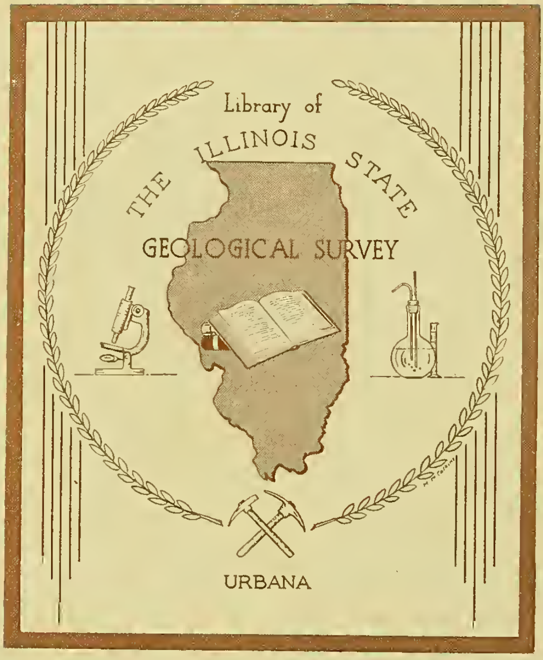

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GEOLOGICAL INFORMATION FOR MANAGING THE ENVIRONMENT*

John C. Frye

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INTRODUCTION

As I consider the topic to which I am to address myself, namely "Geological Information for Managing the Environment," it occurs to me that few words have broader scope than "geology" and "environment." One advantage of such a broad topic is that it should allow ample latitude. For that matter, it might be contended that the term geology, since it means the study of the Earth, includes inherently all factors of the environment. Be that as it may, the professional geologist has traditionally restricted his field of work within this extremely broad definition to applications of the geological sciences to the crust of the Earth and generally has excluded other aspects of the environment. Many geologists, restricting themselves still further, have concerned themselves largely with the discovery of useful materials and their extraction from the rocks of the Earth's crust, or with the purely scientific objective of deciphering the history of the Earth and its past life.

In contrast, a relatively small group of geologists have been admirably successful in the application of geologic data to solutions of problems encountered by the engineer on construction projects, but these applications commonly have been concerned with immediate problems of construction, their feasibility, and ultimate safety. Also in the realm of environmental applications should be included the extensive work being done by ground-water geologists, which involves both the development and management of this major resource.

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*Prepared for the Symposium, "Limitations of the Earth—A Compelling Focus for Geology," held at the University of Texas, Austin, November 16-17, 1967.

Only in the present decade has a general realization developed that—in spite of the program for the exploration of space—the physical limitations of the Earth's crust and its resources are relatively permanent as far as man's destiny is concerned. This realization, especially on the part of geologists and planners, as well as of other officials in a position to utilize the data geologists can provide, now gives promise that man will in the future be better able to cope with the environmental problems arising from the population explosion.

In my personal opinion there seems to be little doubt that man has reached a point in his civilization where he must precipitously change his attitude toward the Earth on which he must live—or face catastrophy within a few generations. I am not a demographer, but those who are have realistically projected world population growth. When we equate their projections with our best geologic projections for world production of those natural resources required to support an ever increasing per capita consumption of raw materials, we see within a few decades an impasse that carries with it no readily apparent solution.

Enough for world affairs, on which I certainly am not competent to speak. Let us turn our attention to our own continent.

Perhaps we can attribute our attitude toward Earth resources to the Mayans a millenium and a half ago who, I am told, worked an agricultural area until it was exhausted and then abandoned it to the jungle to start again in a new area. I seriously doubt that the philosophy prevalent in the early United States was based on any knowledge of Central American customs more than a thousand years earlier, but there were indeed some distinct parallels. During most of our history we have operated on the principle of superabundance. We have assumed that we would always have new acres to develop to the west, north, or south. We have assumed that the Earth's soils and waters were capable of supplying all the biological resources we could ever need. We have assumed that fresh, pure water would always be available for the taking. And, perhaps the greatest fallacy of all, we have assumed that the rocks of the Earth's crust would always be able to supply all of the minerals, metals, fuels, and rock materials for which we might have need.

It has come as a shock to many of us that none of these assumptions of continuing abundance is true. The dilemma of the present was dramatically expressed by the Honorable Stewart L. Udall, Secretary of the Interior, this September*, when he stated

> In the absence of restraint or guidelines for growth, the single-minded, speculative, build-for-today-and-let-tomorrow-fend-for-itself approach has left us with a man-made mess of staggering proportions.

It is quite clear that an important element of the "mess" Secretary Udall refers to has been created by the heedless way in which we have approached the use of our physical environment and our mineral and rock resources.

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*Stewart L. Udall, "Our Perilous Population Implosion," Saturday Review, September 2, 1967, p. 10-13.

On the assumption that I have made the point that a problem exists, and that the problem will get worse rather than better unless we do something about it, let us turn to the ways in which scientific geologic data can, and in the future must, be used in managing man's environment. When I say "managing the environment" I mean, of course, managing man's activities, because the environment is there without our doing anything about it, and it is our activities that despoil it, render it less useful, or modify it in ways that will be for our long-term betterment. I hope that it is this last alternative we have in mind when we refer to management. It is also clear that when we consider managing man's activities we must introduce a word that has been anathema to many in our free-wheeling society, and that word is planning. It is a truism that long-range management must be preceded by long-range planning. It should be our concern in the geological sciences that the planning be based on thoroughly adequate, objective, factual data.

The factual data needed from the earth sciences by the planner and administrator fall into four broad categories. First, physical data on the terrain itself. This category might be called data for physical planning, and it includes information needed for the planning and development of structures and other facilities on the surface, or below it. It is primarily concerned with the general long-range character that the urbanizing area will develop. Second, data for management and disposal of wastes. This category includes the specialized information on the characteristics of the deposits at the surface and of the rocks occurring to depths of thousands of feet below the surface. It is needed for designing and developing facilities for the disposal of the voluminous, varied, and often highly noxious waste products from our society. Third, data for water resource development and management, including continuing water availability, water quality, and water for recreation. Although this category involves the joint effort of many scientific and technical disciplines, geologic data are needed in most aspects of development, particularly in the management of ground-water resources. And fourth, data on the full range of usable rock and mineral materials and subsurface fluids that will assure an adequate supply of the great variety of necessary raw materials, including those needed now and those for which it is anticipated there will be a need in the future, to maintain our civilization in a manner compatible with our intensive occupation and utilization of the Earth's surface.

GEOLOGIC DATA FOR PHYSICAL PLANNING

The first of these general categories—data for physical planning—superficially appears to include the same activities as those carried on by the engineering geologist, and in a semantic sense perhaps it does. But the items of data needed range from topographic maps, geologic maps, and soil mechanics determinations to predictions of landslides or of the response of clay minerals in glacial till to man-introduced chemicals and are far broader in scope than the subjects traditionally covered by the engineering geologist. Many of the geologic data needed in this category can be produced by currently conventional methods of research, but, to be effective, the research program must be oriented toward environmental applications. Furthermore, the results must be presented in a form that is readily understandable

to and usable by planners and administrators who rarely are familiar with science and virtually never have a working knowledge of the geological sciences.

Perhaps the best way to explain what I mean by environmental orientation is to cite a few examples. Within this category there are some items that have been well covered by the national press, among them the development of potential techniques for the prediction of naturally occurring earthquakes on the west coast, and the man-induced earth tremors in the Denver area. I shall not dwell on these. Rather, I shall use a few examples of a more prosaic type that have had little or no public attention and have not even attracted the notice of most geologists. I am sure that you will pardon me when I draw examples from the program of my own organization, the Illinois State Geological Survey, because that is the program I know best.

The first example is a laboratory study involving clay mineralogy, petrography, and chemistry. It was prompted by numerous incidences of structural failure of earth materials. In rapidly expanding suburban areas there has been a drastic increase in the use of septic tanks and, simultaneously, a rapid increase in the household use of detergents and water softeners. Research data were not available on the changes that might be produced in earth materials by the effluent from septic tank systems that contained these chemicals. A laboratory research program was initiated to study the changes induced in the clay minerals by these chemical substances so that we might be able to predict the changes that might occur in the structural characteristics of commonly occurring surficial deposits, particularly glacial till, loess, and fine-textured alluvial and lacustrine deposits. Preliminary results showed that the materials in septic tank effluent did, indeed, produce significant and undesirable changes in the properties of these surficial materials. These data, prepared in a semipopular form, were presented in a mimeographed "Environmental Geology Note" and distributed to planners, health officials, architects, and other groups in the state that might have need of the information.

In strong contrast to such a sharply focused and specific study is a second example provided by the McHenry County, Illinois, Project. McHenry County is at the northwest fringe of the Chicago metropolitan area and is just now being significantly affected by spreading urbanization from that metropolitan center. The county government organized a regional planning commission, which called upon the State Geological Survey, the University of Illinois Agricultural Experiment Station, and the United States Soil Conservation Service to collect data on the physical environment essential to wise, long-range planning. As some of the fields of activity of these three agencies overlapped, they cooperated informally so that they could most effectively work with the planning commission. Essential to the project are the relatively modern topographic maps that cover the county. However, even though much of the county had been geologically mapped in some detail previously, several man-years of geologist time will be devoted by the Geological Survey to the project. The McHenry County physical environment project will include the following 10 areas of study by the Geological Survey.

1) Analysis of the major physiographic units within the county.

2) Relation between surficial geologic units and soil series units, to be done in cooperation with the Soil Conservation Service.

3) Subsurface stratigraphy of the unconsolidated deposits.

4) Occurrence and character of glacial drift and bedrock aquifers.

5) Geologic feasibility of water-resource management programs.

6) Occurrence and characteristics of construction materials, including sand and gravel, rock products, and borrow material.

7) Characteristics and potential uses of clay deposits.

8) Economic value of mineral resources.

9) Engineering characteristics of the various geologic units.

10) Geologic evaluation of surface reservoir conditions and of proposed reservoir sites.

The approach to these areas of data development includes field work by Pleistocene geologists, engineering geologists, ground-water geologists,and economic geologists, and, in the laboratory, stratigraphers, chemists, mineralogists, and economists will conduct subsurface studies of cores and cuttings of the surficial Pleistocene deposits and of the deeper Paleozoic rocks, make chemical analyses, mineralogical analyses, textural analyses, physical properties determinations, statistical compilations, and economic analyses of the several mineral resource situations.

The results of these studies will be compiled on interpretative maps by geologists of the Geological Survey, which in turn will be combined by the planning commission with the results of studies by the other two agencies, and by the commission itself, for preparation of maps indicating recommended uses. These maps, together with explanatory nontechnical text, then can serve as a basis for county zoning and long-range development planning.

A third example involves a similar approach, but on a much smaller scale. It is represented by data requested by the Committee on Planned Development for the Naperville, Illinois, area. Naperville is a western suburb of Chicago in DuPage County and the study was concerned with information for the territory within the jurisdiction of the Naperville Community Council. Geologic data, including many items similar to those listed for McHenry County, were prepared and furnished to the committee. In order to make the information available to the public, a report has been prepared and will be distributed in mimeographed form.

A project of a much more detailed type can serve as a fourth example. It is being done on an experimental basis for two 7½-minute quadrangles south of O'Hare Airport on the west side of metropolitan Chicago. From available logs, engineering borings, cores, and other data, maps will be plotted showing the configuration of the bedrock surface. Also, test data on the deposits overlying the bedrock in the same quadrangles will be plotted

in an attempt to show graphically the engineering properties of the materials. If it proves to be feasible to present such data in a meaningful way on maps, it is envisioned that the whole metropolitan region would eventually be mapped in the same way.

I should make it quite clear that I do not mean to downgrade in any way the traditional job of the engineering geologist. His work is an essential part of applying geologic data to managing the environment, and its importance will continue to increase in the future. Examples are all about us and do not need to be repeated here.

GEOLOGIC DATA FOR DISPOSAL OF WASTES

Our second category of environmental geologic information includes those geologic data needed for proper and safe development of waste disposal facilities. Man has developed the propensity to produce waste materials in progressively increasing quantity and in an ever increasing variety and degree of toxicity and noxiousness. Waste products result from manufacturing, processing, and mining, but of even greater concern is the concentrated production of waste by the inhabitants of our urban areas. In the past we have used fresh water to dilute liquid waste and the atmosphere to dilute the gaseous waste products of combustion. But, now, even the general public is aware of the fact that we are exhausting the diluting capacity of both of these media. Along the sea coasts there is still the ocean—although even the ocean is being restricted as a waste disposal medium—but in the vast region of the continental interior we have no ocean in which to dump our wastes. We have instead only two choices, the essentially complete purification of the waste materials, which would involve unprecedented monetary outlays, or the use of the rocks of the Earth's crust for the future expansion of disposal capacity. Geologists, who have traditionally been concerned with the discovery of valuable deposits and their extraction from the crust, now must also concern themselves with the study of the crust as a possibly safe place to dispose of harmful waste products.

Underground Disposal

Petroleum geologists were introduced to one aspect of the problem of large quantity underground disposal more than a quarter of a century ago, when it became necessary to find methods for injecting into deep wells the increasing quantities of brines produced with petroleum in our oil fields. However, it was not until population densities approached their present levels that we became genuinely concerned with the most critical problems of the future—namely, the safe disposal of toxic materials in large quantity other than by dilution. As some of these toxic materials are destined to increase at an exponential rate in the future, it is obvious that we must devote our best geologic effort to solution of the problems of disposal.

It is gratifying to note that the problem of disposal of high-level and intermediate-level radioactive wastes has attracted a major research effort. Probably the intensive effort has been made because these radioactive materials are obviously so highly dangerous for such a long period of time. With the projected production of electricity by nuclear

energy indicating rapidly increasing quantities of radioactive wastes in the future, it became self-evident that before the turn of the century a problem of gigantic proportions would develop. Perhaps of equal importance were the facts that the United States Atomic Energy Commission had the responsibility for these dangerous waste materials and the money to do something about it, and that the Oak Ridge National Laboratory had the desire to pursue this type of research. In any case, disposal methods by hydraulic-fracture injection of slurries into shale and by deep burial in bedded salt have been demonstrated, among others, to be feasible methods of disposal for intermediate and high-level radioactive wastes. Although both of these methods were developed on the basis of a large background of geologic data and a wealth of technologic "know-how" that had been accumulated in the petroleum and mining industries, it was necessary to carry out extensive research and development programs before these technologies could be adequately and safely adapted to the solution of this highly specialized problem. Unfortunately, we have a far less sophisticated knowledge about safe and adequate disposal of the enormously larger quantities of waste materials being generated by the inhabitants of our cities.

Again, let me turn to my own state of Illinois for some illustrations of the unspectacular but volumetrically large and constantly growing problems of disposal in the geologic environment. It might be well to note that Chicago is the nation's largest city remote from oceanic salt water, and that because Lake Michigan, on which it is located, serves as its water supply, all of its waste disposal must take an inland direction.

Solid waste disposal is generally accomplished by sanitary landfill, and the State Geological Survey is commonly asked by the State Department of Health, as well as by some local health units, to make geologic evaluations of proposed sites. Unfortunately, however, precise and universally accepted criteria for this type of evaluation have not been developed. To help establish such needed criteria for site evaluation, a cooperative project was started by the University of Illinois, the State Department of Health, and the State Geological Survey, with some financial assistance from the U. S. Public Health Service. Several disposal sites of differing geologic character are being intensively studied by coring, instrumentation of test holes, and a range of analyses of the effluent liquids as well as the solid materials. In addition to the obvious items of laboratory determinations of texture, permeability, strength characteristics, clay mineralogy, and thickness of low permeability units protecting the aquifers, data that must be obtained include the less obvious effects of the effluent on the structural character of the deposit, the chemical modification of the leachate by the mineral matter itself, and the microflow patterns in materials generally considered nonpermeable. To make some of these determinations it is necessary to examine the chemical composition of the liquids as they enter the geologic units as well as the chemistry and mineralogy of the containing deposits. In order to achieve the degree of precision necessary, a wide range of analytical techniques is being used, such as X-ray fluorescence, atomic absorption and neutron-activation, in addition to X-ray diffraction and other classical methods of mineral and chemical analysis.

Near-surface disposal by landfill or lagooning methods requires detailed studies of the surficial Pleistocene deposits as well as of the underlying bedrock. On the other hand, deep-well disposal of industrial

wastes requires subsurface studies of the character and regional continuity of the deep rock units as well as information on aquifers at all depths. For such purposes our Survey's file of 180,000 logs and cuttings or cores from more than 50,000 bore holes, many of them put down in the search for oil, are of extreme value. As a matter of fact, it may well be that our extensive files of subsurface data, started many years ago as an aid to exploration for oil and other mineral resources, including ground water, will in the future have their greatest value as a guide to deep disposal and for developing sites for underground storage of gaseous and liquid materials. Geologic data for deep disposal involve a combination of the types of information needed for the exploration for both oil and water plus a knowledge of the characteristics of the low-permeability confining beds of shale or clay. The mineralogy of the disposal beds and their confining beds also must be known in detail in order to predict possible changes that might be produced by the injected wastes.

Atmospheric Disposal

An example of a totally different type of pollution problem is represented by sulfur compounds and other undesirable constituents produced by the burning of coal, oil, and gas, and discharged into the atmosphere. As bituminous coal is a major resource in our region and is used in large quantities, we have several research projects directed toward this problem. Some of this research is in part supported by the United States Public Health Service. It is rather astonishing that although coal ash has been studied in detail for many years we have had relatively little data on the form in which these contaminants occur in the unburned state, and obviously, if we are to modify or remove them, we must know their character in detail. For this reason our coal research program includes a detailed, fundamental study of the indigenous mineral matter in coal. This is being done by low-temperature oxidation followed by X-ray diffraction, instrumental and classical chemical analyses, and by petrographic and chemical studies of the coals. Another project is directed toward mechanical beneficiation of coal, and still another is concerned with chemical additives. Basic research in coal petrography may also yield data helpful in this area. One solution to this problem, in the long term, may result from the research going on elsewhere in the country on gasification and liquefaction of coal and the necessary accompanying removal of the undesirable constituents.

GEOLOGIC DATA FOR WATER RESOURCES AND MANAGEMENT

The third category of data for the physical environment is concerned with water, its occurrence, quality, continuing availability, and pollution; its use as a resource, as a diluent, as a facility for recreation, and as an aesthetic attribute. It would be unrealistic to class the many facets of water and water use as an aspect of environmental geology because many of the problems and areas of data collection fall mainly into the province of the engineer, the chemist, the biologist, or the geographer. It would be equally unrealistic to exclude water from the subjects requiring significant and major data input by the geologist, because to a greater or lesser degree an input of geologic data is needed for the proper development and management of each of these aspects. The occurrence, availability,

development, and replenishment of ground water require major attention by the geological scientist because all of these aspects are directly controlled by the character of the rocks at, and to considerable distances below, the surface.

Of the four categories of environmental data we are discussing, water resources and water pollution are clearly the most widely publicized in the national press and generally recognized by both the public and municipal planners and administrators. Furthermore, within governmental agencies and within industry an extensive cadre of earth scientists specializing in water-related problems has developed. In my own state, geologists and geophysicists of the Geological Survey cooperate with engineers and chemists of the State Water Survey, and both agencies cooperate with municipalities and other governmental units.

There are many excellent examples of the application of geologic data to management of water resources, ranging from dam site evaluations to the mapping of aquifers and determination of areas suitable for artificial recharge. These are well known and I shall not take time to describe them specifically. Before we leave this category, however, I should point out that, in contrast to the rocks and minerals of the Earth's crust, water is a dynamic and renewable resource and therefore, at least in some cases, is in fact subject to management and even the long-range correction of the effects of unwise practices in the past. Here we may actually be able to manage an element of the environment rather than simply manage man's use of it.

As an item of environmental geology we must include complete and adequate mapping of aquifers containing potable waters at all depths; evaluation of these aquifers from the standpoint of transmissivity and recharge potential; evaluation of potential areas of artificial recharge; and evaluation of geologic feasibility of all possible dam and impoundment sites.

RELATION OF RAW MATERIAL SOURCES TO URBANIZATION

Perhaps the most complicated aspect of environmental geology is our fourth area, which is the problem of assuring adequate supplies of mineral and rock raw materials for the future, and especially assuring their availability in areas where they are most needed. In this fourth problem area we have a mounting and intense conflict of interest for land use in and adjacent to our urbanizing regions. This conflict exists because the dedication of an area to buildings and pavement removes the possibility of extracting rock or mineral raw materials from the same area. Furthermore, it is made more difficult because both parties to the conflict have traditionally had slight regard for the problems of the other. The commercial producer of rock or mineral products has explored for the best deposit available from both a physical and economic standpoint. If it was a bulk commodity, with low unit value and high transportation cost, he has attempted to develop a pit or quarry as near as possible to the point of consumption, but he has not been particularly concerned with aspects of urban development other than transportation routes. On the other hand, the urban developer has planned surface installations with almost complete disregard for the presence or absence of rock and mineral deposits which, by his

developments, he is rendering unavailable, even though they may be urgently needed for community developments in the near future. As a further complicating factor, the traditional attitude of the government bodies empowered to make and enforce zoning laws has been to adopt, quite understandably, the attitude of the urban developer and to regard the operations of a mineral industry as of little consequence to the metropolitan area, or perhaps even to view it as an undesirable item in the region.

It is vital that the collision course of these two attitudes be diverted and that compatible working relationships be developed so that mineral resource development can move forward in harmony with, and as an integral part of, the urbanizing regions, because an artificially produced lack of essential construction materials and raw materials for industry will eventually distort, or even strangle, the metropolitan region itself.

In regions remote from metropolitan centers, the geologist continues to pursue his traditional role of exploration for commercially usable resources, evaluation of geology for engineering structures, and location of ground-water supplies. However, in urbanizing regions his role is changing and his task is becoming more exacting. From the geological sciences is needed an accurate and detailed description and mapping of all rock and mineral resources, not only in, but also surrounding, urbanizing areas. These data should extend as far as reasonable haulage distances for bulk commodities from the metropolitan centers, and they should include not only currently developed grades of deposits but also those grades that might have utility during the coming quarter to half a century. Research directed toward the identification of substitute materials and toward meeting more exacting and different specifications for future needs is called for to meet this last requirement. It is only with fully adequate basic data that proper planning can be done. Information about natural resources is just as essential a part of these needed data as are flood hazard maps, physical data maps for engineering projects, and aquifer maps indicating the occurrence of ground-water supplies.

I have my own state of Illinois to illustrate the several points I have tried to make. I must admit, however, that although we have been making a concerted effort in the area of resource mapping, the manpower available in our Survey does not permit the rate of progress that seems desirable. We are preparing sand and gravel resource maps, limestone and dolomite resource maps, evaluating the shale and clay resources, mapping and evaluating ground-water aquifers, preparing regional summaries of the mineral resources and mineral industries, and preparing mineral economics analyses of the various regions of the state. However, our rate of progress seems to us to fall short of our own projection of the needs for data in the coming decades. In explanation it should be pointed out that we also have the task of carrying out an extensive program of research and service on location, characterization, analysis, and utilization of oil, gas, coal, zinc, lead, fluorspar, clay, limestone, and other mineral resources—as well as geologic mapping—in the extensive nonurban region of the state, and there is a limit to which a 145-man organization can be stretched to cover an entire state.

An area of research that clearly is not of itself environmental geology, but which may, nevertheless, make substantial contributions to this problem area in the future, is the imaginative laboratory attack on

beneficiation of materials not now usable and the development of satisfactory substitute materials. I have referred to this in the case of the potential for commercial development of liquid and gaseous fuels from coal, and the environmental changes that may result from such developments. Many other possibilities exist, some of which we have not yet thought about. Although much of the work in this area will be by chemists and engineers, as it comes back to a rock or mineral source that has not formerly been used for the intended purpose, the problem inevitably returns to the realm of the geologist. For that reason geologists, and particularly those concerned with environmental applications, should at least keep abreast of such developments and their economic implications so that they will be able to better predict raw material needs of the future.

Before I leave this fourth area of our discussion, I feel compelled to at least mention some possible directions that urban planning may take in its treatment of the physical environment and mineral resources. It seems to me that the concept of multiple land use, and particularly multiple-sequential land use, must become an essential part of our thinking. There are many possible examples of this concept but as an illustration let me set up the simplest possible hypothetical one. A floodplain area subject to infrequent flooding and underlain by commercially usable sand and gravel deposits might be zoned initially for open space and recreation until such time as the construction material was needed by the expanding metropolitan complex. The area could be utilized next as a source for the needed material, until the production operation had exhausted the sand and gravel. The area could then be returned to recreational use, perhaps with the addition of a lake. True, this is a simple and obvious example, but wise, farsighted planning will produce many more examples that are more complex, sophisticated, and imaginative. We must continually remember, however, that for any such plan to be successful, it must be preceded by the gathering of detailed information about the location and character of the desirable resources, as well as data about the topography and other physical aspects of the surficial deposits.

SUMMARY

In summary, perhaps I should start by a hackneyed quote — "It's later than we think." When we look, on the one hand, at projected rates of growth and of per capita consumption of resources, and, on the other, at the rate of land withdrawal by urban spread, highway construction, and other virtually nonreversible uses of land, perhaps the phrase is not so hackneyed after all. Man's physical living space is including a progressively increasing percentage of the Earth's surface, and the rate of increase is increasing. It is the business of the geological sciences to gather data on the Earth's crust and its resources. Therefore it seems obvious that these data are needed for future planning and management and are truly essential in and surrounding the high-density urbanizing areas. We have considered the geological data in four broad groups.

First, physical data on the terrain needed for physical planning. It was discussed first because it is the most obvious. The sloping hillside covered by pasture or wheat field is quite visible before it is converted to city street, factory, or interstate highway, and the need for adequate foundations has long been well understood.

Second, we discussed problems of waste disposal. Perhaps these problems also should be obvious, but unfortunately they do not seem to be. The need for a proper "underpinning" for a waste disposal facility is only now coming to be generally understood.

The third category includes data from the geological sciences needed for the evaluation, utilization, and management of water and its use, ranging from domestic supplies to recreation. Although in some water problem areas the needed input of geologic data may be minor, in others it is a major and essential ingredient. In this area we have general public concern and at least a measure of understanding. Water may be the one item of the physical environment that can be managed.

Fourth, and last, was discussed the need for assessing, evaluating, and mapping the rock and mineral resources in and adjacent to urbanizing regions, and the incorporation of such data as an integral part of long-range planning. These considerations not only have not been obvious—in spite of economic analyses that demonstrate their importance to metropolitan areas—but seemingly there is still a lack of general recognition of this need.

When we take these four areas of application and combine them into an integrated whole, we have what we have termed "Environmental Geology." I am, of course, using geology in the broad sense of the Geological Sciences, or, as some educators now prefer to translate it, Earth Sciences. Actually, the term "Environmental Geology" means an attitude of mind, an orientation, the application of the best and most sophisticated scientific work we are capable of doing to the problem of accommodating a rapidly shrinking living space and resource base to the needs of man.

I wish to conclude with a comment addressed particularly to those in the geological sciences. I urge that you give serious thought to the conversion of the truly great stock of scientific data available about the Earth's crust to a new and vital applied field, the physical environment of our urbanizing areas. In this regard, you should remember that the success of geologic exploration for mineral resources—be they liquid, gaseous, or solid—has been based on a mutual understanding and rapport between the exploration geologist and management. They both knew what they wanted to accomplish, and each learned to communicate effectively with the other. In order to do this effectively in the environmental area, you must learn enough about the problems of the planner and administrator to enable you to put geologic data into a form that can be used by those who need it. In addition, new research oriented specifically toward the solution of many of these specialized and formerly unrecognized problems is needed. It is also necessary that we approach these problems with the most sophisticated research tools at our disposal. Happily, efforts are being made in these directions at many places across the country, but still far too many geologists are talking to each other rather than to the public, and, in management of the environment, the public is "management."

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1. Controlled Drilling Program in Northeastern Illinois: J. E. Hackett and G. M. Hughes. April 1965.

2. Data from Controlled Drilling Program in DuPage County, Illinois: Jean I. Larsen and C. R. Lund. May 1965.

*3. Activities in Environmental Geology in Northeastern Illinois: Jean I. Larsen and J. E. Hackett. June 1965.

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